National 4 Chemistry

Unit 2
Nature's Chemistry

Material sourced from BBC Bitesize Revision Website

1 - Fuels

Fuels are one of the most important substances on Earth. They cook your food, heat your home and keep the cars and trains running. Without fuels the world would be a very different place.

A fuel is any compound which has stored energy. Combustion is burning a fuel in oxygen, which gives out heat energy and is called an exothermic reaction. The energy contained in the fuel is released when it burns.

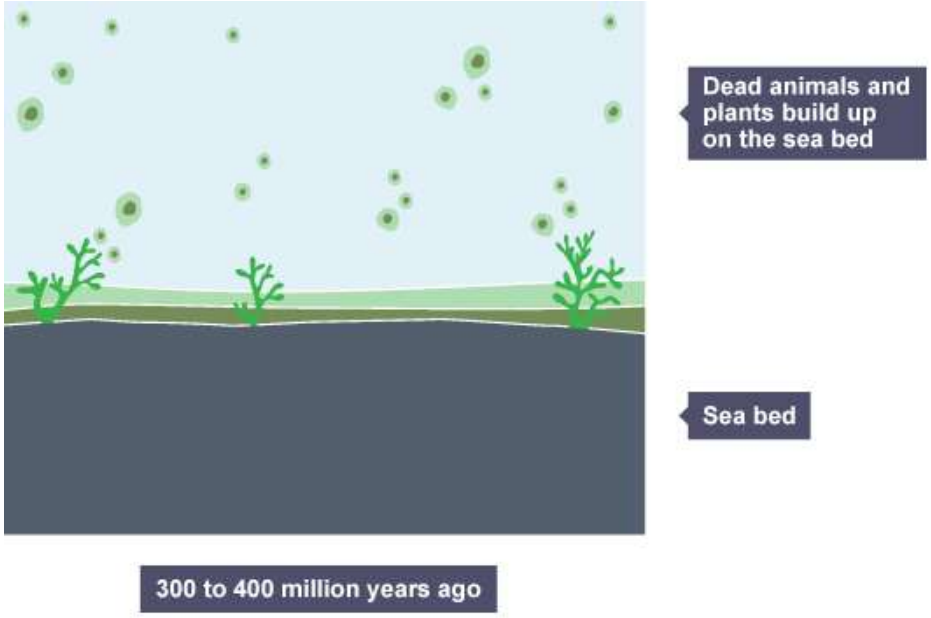
Many of the fuels we use in everyday life are obtained from fuels called fossil fuels.

Fossil fuels like coal, crude oil and natural gas have been formed over millions of years from dead plant and animal remains which have been buried.

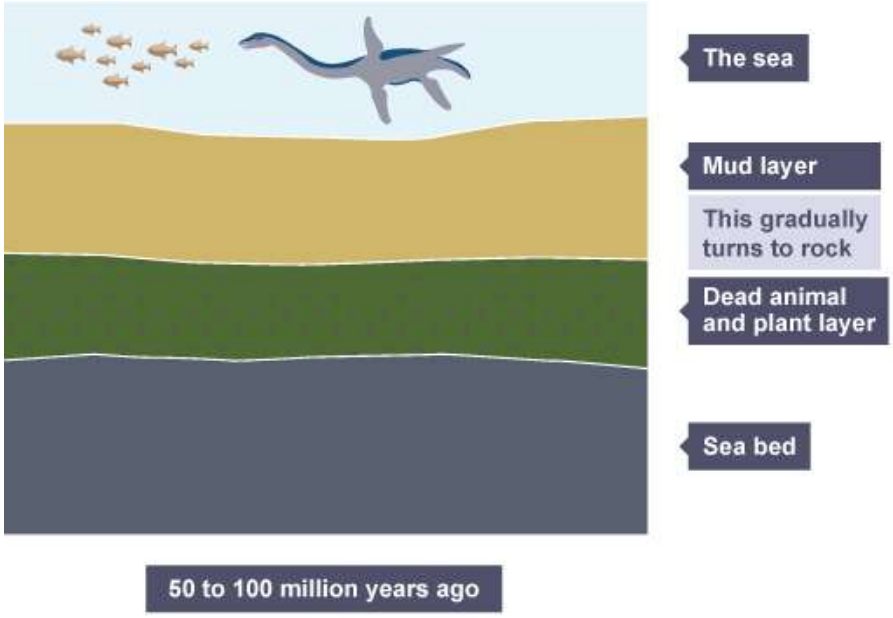
a) Formation of Crude oil

Millions of years ago small animals and plants died and fell to the bottom of the sea. Their remains were covered by mud.

Step one



Step two



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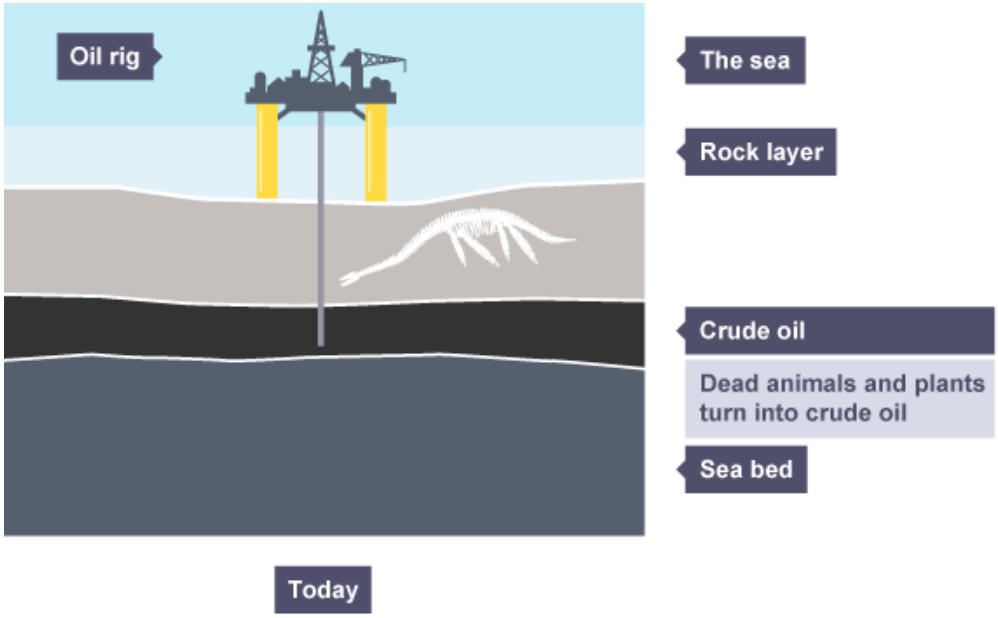


The mud eventually turned to rock. This rock put a lot of pressure on the dead animals and plants. Rocks around them also heated them up. Together the heat and the pressure turned the remains into crude oil. It was important that no air or oxygen was present.

Fossil fuels are finite (non-renewable) energy resources. Their supply is limited and they will eventually run out. Fossil fuels do not renew themselves, while fuels such as wood can be renewed as trees capture energy from the sun in chemical reactions. This is the energy that is released when they burn.

Fossil fuels release carbon dioxide gas when they burn which adds to the greenhouse effect and increases global warming. Of the three fossil fuels, for a given amount of energy released, coal produces the most carbon dioxide and natural gas produces the least.

Coal and oil contain sulfur impurities. When these fuels burn, the sulfur burns too which releases sulfur dioxide (SO_2) gas. Sulfur dioxide causes breathing problems for living creatures and contributes to acid rain.

b) Combustion

When a substance burns, it reacts with oxygen. This is known as combustion. All combustion reactions are exothermic because they release energy, eg heat energy is given out when methane is burned in a Bunsen burner.

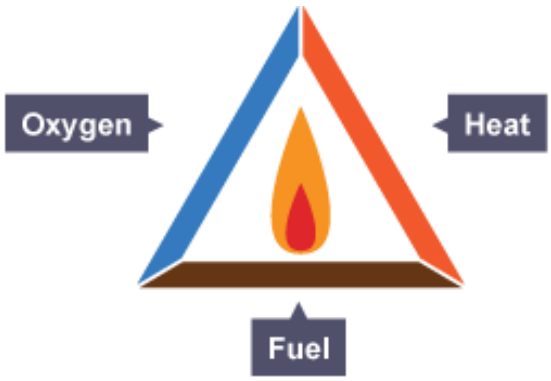
As combustion is the reaction of a fuel with oxygen, then it is obvious that oxygen must be present for combustion to take place. Normally, the oxygen required in combustion reactions comes from the air.

Only 21 per cent of the air we breathe is oxygen, 78 per cent is nitrogen and 1 per cent other gases.

The Fire Triangle

Fire can be explained using a fire triangle. The triangle has three sides, fuel, oxygen and heat.

Each of these sides represents a key element for fire to occur. If one of them was removed, the triangle would collapse and the fire would go out. Fire-fighting relies on this principle. The fire will extinguish once the fuel runs out, but it is often unsafe to leave fires that long. Water removes the heat, but different types of fires need to be tackled in different ways.



Chip pan fires

Chip pan fires should be extinguished by covering it with a damp cloth. This stops the oxygen getting to the fire. Water must NEVER be put on a chip pan fire.

Petrol fires

There are buckets of sand on petrol forecourts. Adding sand to a petrol fire stops the oxygen getting to the fuel.

Electrical fires

Pouring water on electrical fires to remove the heat is very dangerous. If a carbon dioxide fire extinguisher is used, no oxygen can reach the fuel.

Other fire extinguishers such as powder and foam prevent oxygen from getting to the fuel

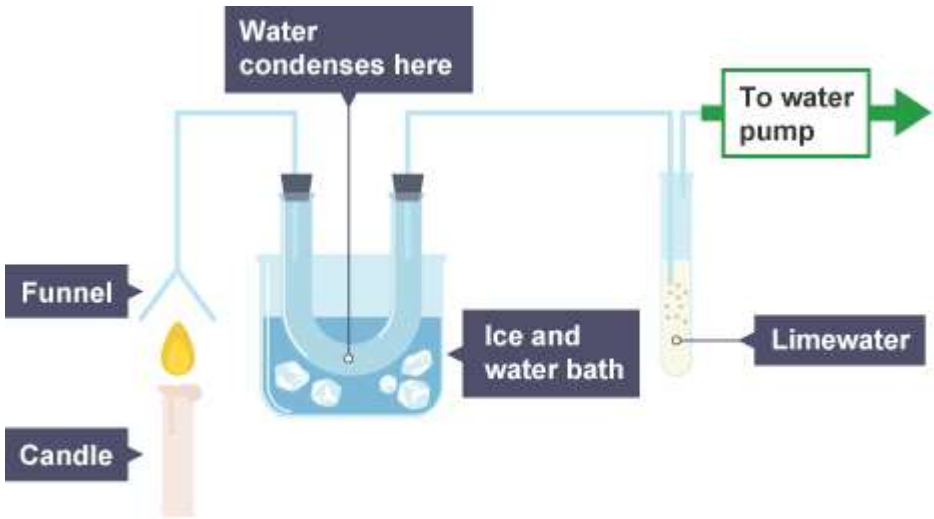
c) Products of combustion

When a compound burns it reacts with oxygen. Because of this we can predict what the products of the reaction will be. The oxygen will combine with each individual element in the compound.

Since hydrocarbon fuels only contain two elements, we always obtain the same two products when they burn. In the equation below methane (CH_4) is being burned. The oxygen will combine with the carbon and the hydrogen in the methane molecule to produce carbon dioxide (CO_2) and water (H_2O).

Equation: $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$

The products from the combustion of hydrocarbon fuels can be identified with the following set up in the lab.



Carbon dioxide gas turns limewater from colourless to milky white. In the above experiment, the limewater in the boiling tube changes colour indicating carbon dioxide is produced by combustion of the hydrocarbon fuel.

If water is produced it will condense in the U tube cooled by the ice water. This results in cobalt chloride paper changing colour from blue to pink.

d) Incomplete combustion

While carbon dioxide and water are produced when hydrocarbons burn in a plentiful supply of oxygen, complete combustion is not always possible. If the fuel is burned with a limited supply of oxygen, incomplete combustion can occur and the following pollutants can be formed:

- carbon monoxide (CO) – a poisonous gas
- soot - unburned carbon which leaves as dirty particles

Air pollution from the burning of hydrocarbons can be reduced by special exhaust systems. Car exhaust systems have catalytic converters. Expensive transition metal catalysts are used to convert the pollutant gases into less harmful gases:

carbon monoxide + nitrogen monoxide → nitrogen + carbon dioxide

Equation: $2CO + 2NO \rightarrow N_2 + 2CO_2$

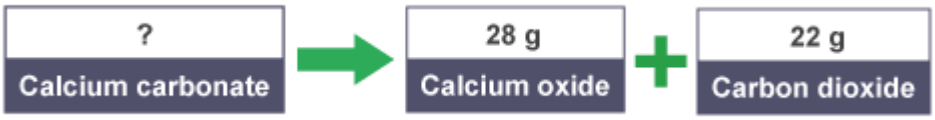
e) Conservation of mass

When things burn, it looks like they are destroyed, but during any chemical reaction no particles are created or destroyed. The atoms in fuels are simply rearranged from the reactants to the products during combustion. The products may have different properties to the reactants.

Mass is never lost or gained in chemical reactions. We say that mass is always conserved. In other words, the total mass of products at the end of the reaction is equal to the total mass of the reactants at the beginning.

Example One:

Step 1:



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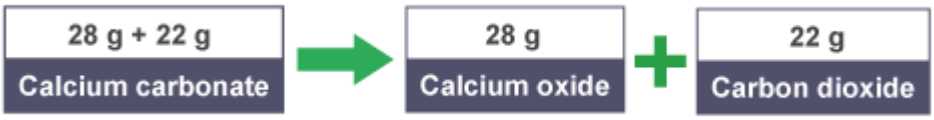

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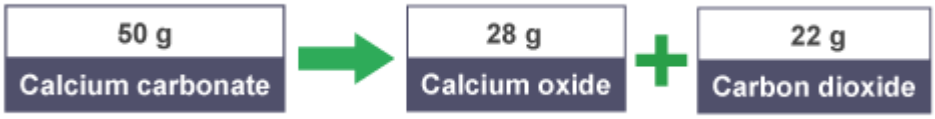


Example Two:

Step 1:

Step 2:

Step 3:

f) Biomass

Biomass is biological material that has been recovered from once-living organisms. It can be used as a source of biofuels (a renewable energy source) to reduce our dependence on fossil fuels, and to help reduce air pollution. Using biomass as fuel still puts carbon dioxide back into the atmosphere, but it's the same carbon dioxide taken from the air as the biomass was produced. The use of biomass for energy production is carbon neutral.

Examples	**Processing**	**Use**
Biogas	Bacteria break down sewage in a digester	The methane in biogas can be used as a fuel for heating homes
Bioethanol	Yeast breaks down the sugar in sugar cane to produce alcohol	Bioethanol is used in Brazil to fuel cars
Fast-growing timber	Trees such as willow can be burned in power stations	Electricity is generated using renewable biomass instead of fossil fuels

Fuels Minitest

1 Crude oil is a fossil fuel.

Which one of the following is not a fossil fuel?

- Coal
- Uranium ore
- Natural gas

2 Which of the following terms cannot be used to describe fossil fuels?

- Finite
- Hydrocarbons
- Renewable

3 What are the products formed when a hydrocarbon burns in a plentiful supply of oxygen?

- Carbon monoxide and water
- Sulfur dioxide and water
- Carbon dioxide and water

4 What is the test for carbon dioxide gas?

- Relights a glowing splint
- Turns lime water cloudy
- Burns with a pop

5 Which of the following is an example of a renewable fuel?

- Bio-ethanol
- Oil
- Peat

6 How long ago were fossil fuels formed?

- They are made fresh every month
- The late 1960s
- Millions of years ago

7 Which of the following pollutant gases can be released by burning fossil fuels?

- Sulfur dioxide (SO_2)
- Nitrogen dioxide (NO_2)
- Hydrogen cyanide (HCN)

8 Which of the following is not one side of the 'Fire Triangle'?

- Fuel
- Energy
- Heat

9 Which of these pairs can be produced by incomplete combustion of petrol?

- Carbon dioxide and water
- Carbon monoxide and soot
- Nitrogen dioxide and sulfur dioxide

10 What is the safest way to extinguish a chip-pan fire?

- Throw water at the base of the fire
- Spray the area with a powder fire extinguisher
- Cover the pan with a wet dish cloth

2 - Everyday consumer products

a) Carbohydrates

Plants make compounds called carbohydrates which have a wide variety of uses including foods and fuels. All carbohydrates contain the elements carbon, hydrogen and oxygen. Two of the most common carbohydrates are glucose and starch.

Glucose ($C_6H_{12}O_6$) is a simple sugar unit. From the formula, you can see that it contains twice as many hydrogen atoms as carbon atoms. Starch is a much larger, more complicated molecule. Plants produce glucose during the process of photosynthesis and convert it into starch to store energy. Starch is made by joining together many glucose units.

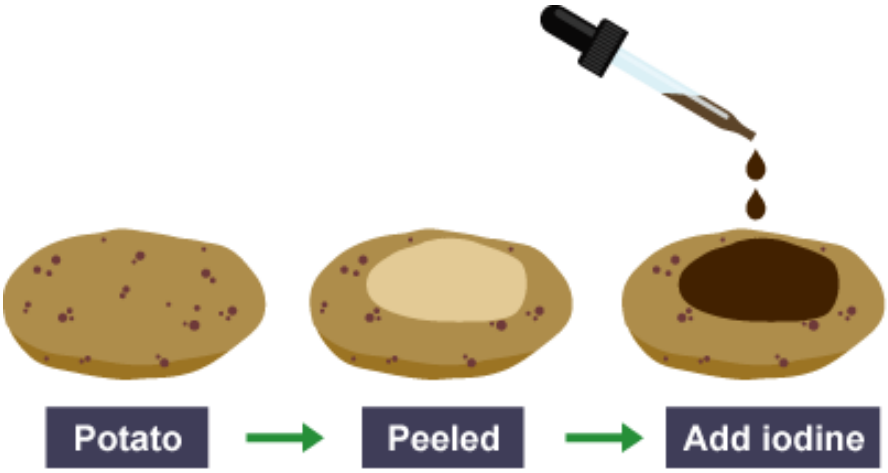
Distinguishing glucose from starch

- Tyndall Beam Effect:

A test to distinguish starch from glucose is to shine a beam of light through 'solutions' of each. This is also called the Tyndall Beam Effect. Dispersal only happens in starch as the large starch molecules are big enough to affect the light. This is a physical test.

- Iodine Solution

A chemical test for starch is to add iodine solution (yellow/brown) and look for a colour change. In the presence of starch, iodine turns a blue/black colour. It is possible to distinguish starch from glucose (and other carbohydrates) using this iodine solution test. For example, if iodine is added to a peeled potato then it will turn black.



- Benedict's Solution

Benedict's reagent can be used to test for glucose. The test involves heating a solution of the sugar to be tested with Benedict's reagent and observing the colour change of blue to orange. Benedict's reagent will give a positive test result for glucose but not for starch.

- Summary

Carbohydrate	Benedict's Reagent	Iodine solution	Tyndall Beam Experiment
Glucose	Blue to orange	-	-
Starch	-	Yellow/brown to blue/black	Light beam visibly dispersed

Digestion of carbohydrates

During digestion starch is broken down into glucose. Glucose is small enough to pass through the gut wall but starch cannot. This is done in the body using enzymes (biological catalysts) which work best at body temperature. The glucose molecules can then be transported around the body in the blood stream so that they can be used for the process of respiration.

b) Making alcohol

Fermentation is a reaction which breaks down glucose obtained from fruit and vegetable sources to form the alcohol ethanol and carbon dioxide.

An enzyme in yeast acts as a catalyst for the reaction.

$$Glucose \rightarrow ethanol + carbon\,dioxide$$
$$C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2$$

There is a limit to the alcohol content of fermented drinks of about 12 per cent. This is because alcohol is toxic and it kills the living organism yeast, before too long.

Depending on the concentration of alcohol required, fermentation only or fermentation followed by distillation may be used.

Alcoholic drinks known as spirits have higher concentrations of alcohol. These include whisky and vodka and are produced by a process called distillation which separates out the alcohol that has been produced.

Raw Material	Product	%	Method
Barley	Beer	4 - 5	Fermentation
Barley	Whisky	40	Fermentation then distillation
Potato	Vodka	40	Fermentation then distillation
Sugar Cane	Rum	40	Fermentation then distillation
Grape	Wine	12	Fermentation
Grape	Brandy	40	Fermentation then distillation
Grape	Sherry	20	Fermentation then add extra alcohol

The alcoholic content of drinks is measured in units. Some different unit contents are shown in the table below.

Alcoholic drink	Units
Pint of beer	2
Measure of whisky	1
Bottle of alcopop	2
Glass of wine	1

c) <u>Plants to products</u>

Our bodies perform many chemical reactions in everyday life which keep us healthy. Medicines contain drugs (substances that affect the body) that can help the body when it is not working correctly. Antibiotics are drugs that fight micro-organisms present in our bodies that cause illness and prevent our bodies from working properly. Many medicines that we use including aspirin have been produced from chemicals found in nature. Plants produce useful chemicals that chemists can analyse and improve upon.

Everyday consumer products Minitest

1 Which three elements make up carbohydrates?
- Carbon, nitrogen and oxygen
- Carbon, hydrogen and oxygen
- Carbon, nitrogen and hydrogen

2 Which of the following solutions can be used to test for glucose?
- Bromine water
- Benedict's Reagent
- Iodine

3 What is the colour change observed when iodine is added to starch?
- Yellow to blue/black
- Blue to red/orange
- Yellow to colourless

4 What is the molecular formula of glucose?
- $C_6H_{12}O_6$
- C_6H_{12}
- $C_6H_6O_6$

5 Why must starch be broken down into glucose during digestion?
- Our stomachs contain iodine
- Glucose molecules taste sweeter
- Glucose molecules are small enough to fit through the gut wall

6 Which process do plants use to produce glucose?
- Hydrolysis
- Respiration
- Photosynthesis

7 Fermentation is a chemical process that involves breaking down glucose. What two products are formed during this reaction?
- Carbon dioxide and water
- Carbon dioxide and alcohol
- Carbon monoxide and water

8 The fermentation of glucose to ethanol and carbon dioxide by yeast stops when the ethanol concentration gets to about 12%. Why is this?
- The ethanol has destroyed the yeast
- Carbon dioxide has destroyed the yeast
- There is no more glucose left to react

9 What is the method used to increase the ethanol concentration of fermentation products?
- Cracking
- Dehydration
- Distillation

10 Which of these drinks is equivalent to two units of alcohol?
- A bottle of alcopop
- A half pint of lager
- A measure of whisky